Helsinki University of Technology

Laboratory of Wood Technology

Master Thesis

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Harmonising The Internal Log Volumes

TEKNILLINEN KORKEAKOULU — DIPLOMITYÖN TIIVISTELMÄ

Puunjalostustekniikan osasto

Tekijä	Päiväys / Sivumäärä
Tommi Sneck	Päiväys: 29.11.2001 Sivumäärä: 54 +1

Työn nimi

Erään yrityksen sisäisten tukkivolyymien yhtenäistäminen

Professuuri	Koodi
Puutekniikka	Puu-28

Työn valvoja

Prof. Tero Paajanen

Työn ohjaaja

Seppo Vainio

Tämän diplomityön tutkimuksen tavoitteena oli löytää vastaus erään sahateollisuuden yrityksen sisäiseen raportointiongelmaan. Yrityksen eri toimintamaiden omat kansalliset tukinmittaus määräykset tekevät tukkivolyymien sekä käyttösuhdelukujen sisäisen vertailun mahdottomaksi.

Työssä käsiteltiin kahta mahdollista ratkaisuvaihtoehtoa; Maakohtaisten tilavuuskorjauskertoimien määrittäminen ja laskeminen tai teknisen mittausmenetelmän luominen mittaamaan yhteistä tilavuutta, ainoastaan sisäiseen käyttöön, kaikissa toimintamaissa.

Tutkimusprosessi keskittyi kansallisten mittauskäytäntöjen selvittämiseen sisältäen tarkemman syventymisen mittauslaitteisiin, kansallisiin mittaus- ja tilavuuslaskentaperusteisiin sekä muihin tukinmittaukseen liittyviin prosessitekijöihin. Lisäksi tutkittiin tukinkäyttöön liittyviä raportointi- sekä tietojärjestelmiä. Tutkimuksen "sivutuotteena" syntyi myös potentiaalisten laitetoimittajien katsaus tulevaisuuden tukinmittausmenetelmiin.

Tutkimuksen tulos oli selkeä. Yhteinen volyymi olisi parasta toteuttaa yhtenäisen mittausmenetelmän avulla. Tutkimus ehdottaa yhteisen menetelmän pohjaksi Suomessa käytettävien tukkimittareiden tukinkuutiointiperustetta. Tämä vaihtoehto olisi ohjelmointimäärältään vaivattomin ja nopein toteuttaa. Tämän teknisen ratkaisun avulla kansallisten volyymien ero olisi korkeintaan luokkaa ± 7%. Luultavimmin kuitenkin selvästi pienempi eli noin luokkaa ± 4%. Nykyisin kansallisten käyttösuhdelukujen erot ovat aiemman tutkimuksen perusteella jopa luokkaa 10-20%. Tarkan virheen matemaattisen määrittämisen on hankalaa. Erityisesti prosessitekijät vaikeuttavat käytännön mittauserojen arviointia.

Vaikka tutkimuksessa löydetään ratkaisu esitettyyn ongelmaan, liittyy tukinmittaukseen ja sitä kautta mm. käyttösuhdelukuihin paljon epävarmuustekijöitä. Epätarkkojen ja usein monesta lähteestä koottujen käyttösuhdelukujen kuukausittainen vertailu ei voi antaa paljoakaan tarkkaa tietoa jonkun yksittäisen sahan toiminnasta. Käyttösuhdeluvun tarkastelu vuositasolla on kuitenkin tällä hetkellä paras saatavilla oleva työkalu erityisesti yhden sahan raaka-aine käytön seurantaan yritystasolla.

Avainsanat	Kieli
Tukinkäyttö, raportointi, tukkivolyymit, tukinmittaus, volyymin korjauskertoimet, tukkimittari.	Englanti

HELSINKI UNIVERSITY OF TECHNOLOGY
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ABSTRACT OF MASTER'S THESIS

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Title of Thesis
Harmonising the internal log volumes

Chair	Chair Code
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Supervisor
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This Master Thesis focuses on finding a solution to a measuring problem concerning the company internal reporting. The different national measuring principles for sawlogs in all the operating countries of this company, make the comparison of log consumption and yield figures difficult.

In the Thesis two alternative solutions are considered; Either to determine and calculate the volume correction coefficients for each operating country or to develop a uniform technical measurement system to determine common volume for the internal use in each operating country.

The research process was focused to determine national mill measurement practices for sawlogs including more thorough study on measurement equipment, national measuring and volume calculation principles, and other process factors related to log mill measurement. The reporting and IT-systems concerning log volumes were also studied for possible further implementation. As a "by-product" of the study can be considered the review on future outlooks of the potential logscanner manufacturers.

The result of the study was to carry out the volume harmonisation with a technical solution. The study recommends that the common internal volume would be based on the volume calculation used in the logscanners at the Finnish mills. This solution would require the minimum amount of programming because of its simplicity. This solution was also considered to be the fastest to implement. With this technical solution the differences between national volumes could be reduced to very max. ± 7 % level. Most likely the difference would be much smaller around ± 4% max. At the moment the present compared yield figures may have differences around 10-20%. The future accuracy is impossible to determine mathematically, mostly because of the unobservable magnitude of the process errors, that occur during the log measurement.

Though the thesis finds a solution for the existing problem, it still carefully questions the total project of volume harmonisation. Comparing inaccurate yield figures, built of information from various sources on a monthly level does not reveal much of the operation of a particular sawmill. However, it must be admitted that the yield figure monitoring with annual trend is currently the best available tool for monitoring the raw-material use on a company level.

Keywords	Language
Log consumption, reporting, log volumes, volume correction coefficients, log measurement, log scanner.	English

Forewords

This Master Thesis is done as a start-up study for the project of the internal log volumes harmonisation for StoraEnso Timber Oy Ltd (SET). The main customer in the project has been the SET Raw-material team.

I want to thank everybody, who has given me their precious time for this project during these unstable times in the sawmilling industry. Most of all I would like to thank the whole SET Raw-material team, the Thesis project and steering group. Special thanks goes to the "main instructor" R&D Director of SET Seppo Vainio, the project "initiator" Raw-material and By-products Director of SET Elisabet Salander-Björklund, Research Scientist of HUT Tero Lahti and of course Professor Tero Paajanen. I also want to thank my parents and my sister for bearing my constant shouting from the computer room.

Mankkaa 29.11.2001

Tommi Sneck

1 The company

StoraEnso Timber Oy Ltd (below SET) is the biggest timber company in Europe and third biggest in the World, which annual net sales are EUR 1 200 million. The number of personnel is 3 500. SET has 19 sawmills and 13 further processing plants, with total sawing capacity of 5 800 000 m^3 of which further processed 2 000 000 m^3. Both the sawing and further processing capacity and locations are presented in the pictures below.

Picture 1. StoraEnso Timber Oy Ltd locations (SET 26.7.2001)

Table 1. Total sawing capacity of 5.800.000 m^3/a (SET 26.7.2001)

Nordic (Redwood)		*Nordic (Whitewood)*	
Ala	350.000	Kitee	350.000
Honkalahti	410.000	Kopparfors	350.000
Linghed	35.000	Kotka	290.000
Uimaharju	300.000	Tolkkinen	255.000
Veitsiluoto	260.000	Varkaus	330.000
Koski Timber (51%)	90.000		
Total	***1.445.000***	***Total***	***1.575.000***
Central European Timber		***(Whitewood + Redwood)***	
Bad St. Leonhard	330.000	Gruvön	350.000
Brand	305.000	Imavere Saeveski (33%)	290.000
Plana	255.000		
Sollenau	310.000		
Ybbs	600.000		
Zdirec	365.000		
Total	***2.165.000***	***Total***	***640.000***

Table 2. The further processing capacity of 2 000 000 m^3 (SET 26.7.2001)

Nordic (Redwood)		*Nordic (Whitewood)*	
Ala	10.000	Kitee	---
Honkalahti	140.000	Kopparfors	200.000
Linghed	---	Kotka	70.000
Uimaharju	---	Tolkkinen	---
Veitsiluoto	---	Varkaus	---
Koski Timber (51%)	---		
Total	***150.000***	***Total***	***470.000***
Central European Timber		***(Whitewood + Redwood)***	
Bad St. Leonhard	100.000	Gruvön	200.000
Brand	180.000	Imavere	10.000
Plana	160.000		
Sollenau	210.000	Amsterdam	110.000
Ybbs	310.000	Lamco (51%)	80.000
Zdirec	55.000	Wimmer (49%)	240.000
Total	***1.015.000***	***Total***	***440.000***

The SET raw-material procurement in different operating countries is presented below.

Finland

In Finland the total consumption of sawlogs is 4.5 million m^3 per year. 82% of the logs is purchased from Finland, 18% from neighbouring regions. 5% of sawlogs come from StoraEnso's own forests in Finland.

Sweden

In Sweden the consumption of sawlogs is 1.9 million m^3 per year. 100% of the logs is purchased from Sweden, 75% from own forests. All sawlogs from own forests are FSC Certified.

Austria

In Austria the consumption of sawlogs is 2.2 million m^3 per year. 50% is purchased from Austria, 50% from Czech Republic, Germany and other countries.

Czech Republic

In Czech Republic the consumption of sawlogs is 0.8 million m^3 per year
The logs are mainly purchased from Czech, some of them from Russia, Ukraine and Germany (SET 26.7.2001)

2 Background and introduction

Since Ensos Schweighofer acquisition and the following Stora and Enso merger SET has struggled with problems caused by differences in log measurement in the different operating countries. Incomparable log volumes have made it difficult or even impossible to compare specific production figures e.g. yields and raw-material costs. The aim of this thesis is to find out if the log volumes could harmonised.

The Master Thesis research plan is presented below:

Goal

1. To develop a common measuring system for comparing the log volumes at the sawmills in Finland, Sweden, Austria and Czech Republic.

2. Determination of the converting factors, which make possible to compare log volumes and yields in the countries above.

Research process

The research work includes following stages:

1. To determine the log-measuring practices used in Finland, Sweden and Central Europe (below CE).

2. To collect information of log measuring systems and equipment used at SET Mills.

3. To collect and analyse the information about the available equipment for log measuring.

4. To analyse the factors affecting the methods and accuracy of log measurement.

5. Tests for specification of volumes of logs in selected sawmills. The test method shall be chosen based on the analysis of points 1-4 (manual, optical, statistical etc.)

6. Results

7. Conclusions and recommendations including the risk analysis of the accuracy of measurement results.

Organisation

The following group was formed to carry out the project.

Project Group

Lars Johansson
Harri Kautonen
Andreas Kogler
Tero Lahti
Jussi Lemmetty

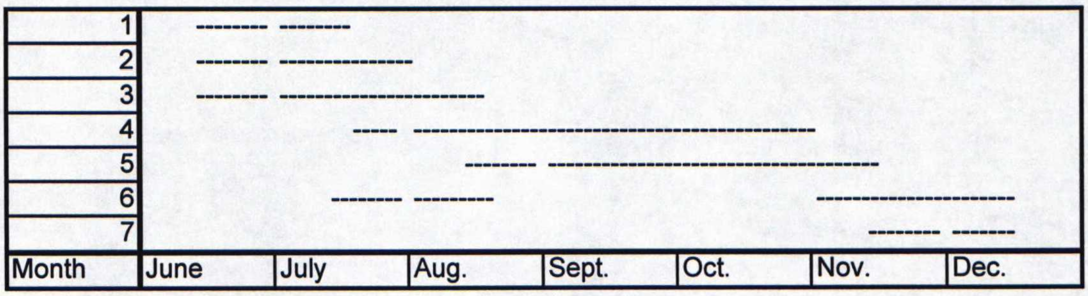
The project was guided by the following group.

Steering Group

Elisabet Salander-Björklund *Chairman*
Pekka Hämäläinen
Dieter Kainz
Tero Paajanen
Seppo Vainio
Tommi Sneck *Secretary*

Time schedule

The work was started on 11.6.2001 and will be carried out according to the following schedule.

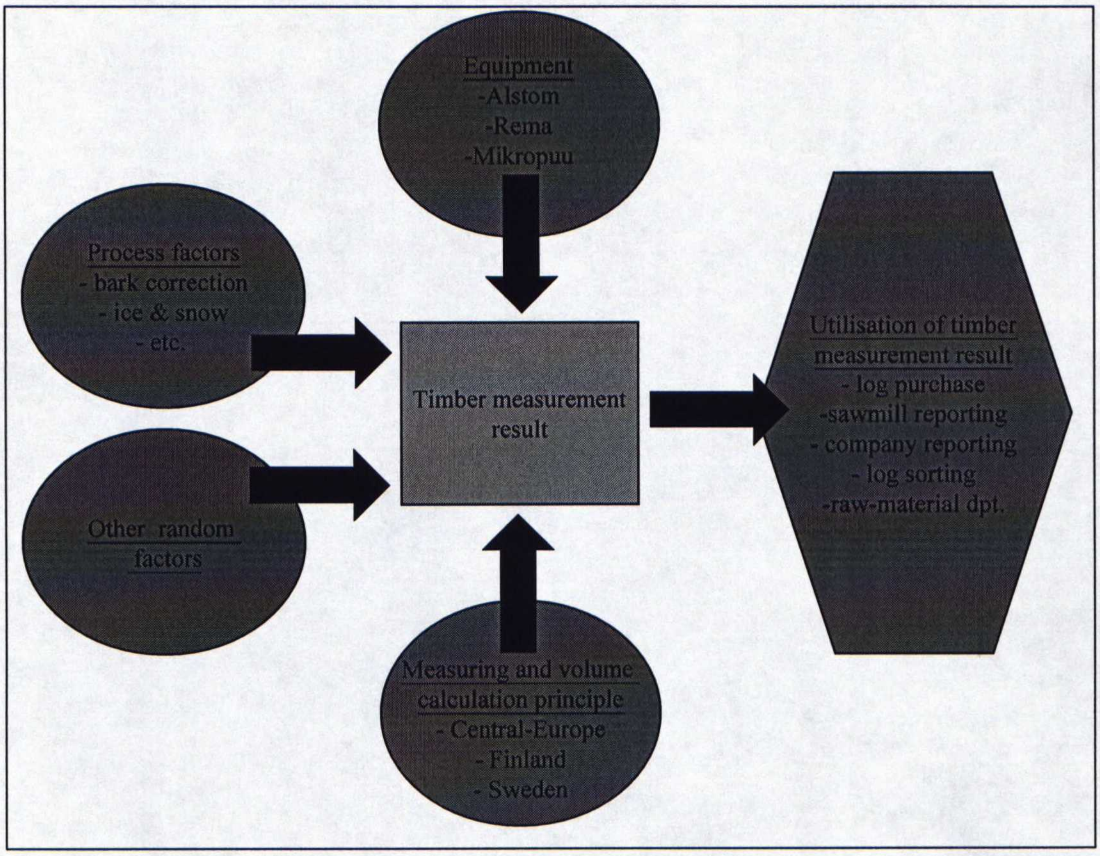


Picture 2. The Master Thesis timetable.

The procedure numbers on the picture 2 refer to the research process stages at page 4 and 5.

3 Research frame of reference: "The Timber Measurement Model"

The timber measurement model combines the questions handled in following chapters 4,5,6 and 7. The model is presented on picture 3.



Picture 3. Timber measurement model.

In the timber measurement model the log measurement result is in case of this study reviewed as a combination of 4 factors:

1. The measurement and the volume calculation principles are, in the case of SET, different in all the operating countries. They are discussed in chapter 4.

2. The equipment creates a certain difference in present log measurement practices and results. Scanner resolution and accuracy can cause differences, which depend on the manufacturer and the model. These factors are handled in the chapter 6.

3. The process factors create also an influence on measurement results. Deviations caused by different operating procedures are evident despite relatively similar instructions. These things are dealt at chapter 7.

4. The utilisation of log measurement results is presented and discussed in chapter 5.

The discussion of timber measurement model factors is followed by the review of existing errors and their magnitudes in the chapter 8.

4 Timber measurement practices

This chapter contains only the practices concerning the mill measurement (optic electronic measurement and control measurement) in each operating country. Practices used in Austria are also used at SET mills in the Czech Republic.

4.1 Finland

The Finnish mill measurement practices are based on several statutes. All sawlogs in the mills are measured with optic electronic measurement, but the purchase between the company's forest department and the seller can be done according to results the of the harvester measurement, single log measurement or optic electronic measurement at the mills. The proportions of purchase according to mill measurement vary from mill to mill. Proportions are presented in table 3.

Table 3. Mill measurement purchase percentages.

Mill	Proportion of log volume paid according to the mill measurement
Honkalahti	20 %
Kitee	65 %
Kotka	7 %
Tolkkinen	40 %
Uimaharju	55 %
Varkaus	10 %
Veitsiluoto	80 %

Generally the volume results from harvester measurement are considered to be 2% bigger than the results from the mill measurement. All invoicing concerning logs between the forest department and SET are done according to the optic electronic measurement. Every SET mill in Finland uses the "solid on bark" volume in production reporting.

According to statutes and regulations the mill optic electronic system should measure the logs as follows:

Length

The shortest log length is measured with 1 cm accuracy and the volumes are calculated according to these lengths. 3 cm deviation from the required log length is allowed. In case the deviation is more than the allowed 3 cm, the length of the log can be calculated according to the next shorter module. In this case both actual and shortened volume must be documented. However, this system is not used for Finnish timber, since it might cause problems at the external log trade. But for the imported timber the mentioned volume reduction is at use. In most of the mills the 3 dm modules run from 40 dm to 61 dm, except Kotka and Tolkkinen mill, which also accept 31, 34 and 37 modules. All these lengths include 10 cm overlength compared to sawn-timber lengths.

Diameter and volume

The diameter is measured in sections, so that the section length should not exceed 30 cm. The diameter should be measured with 1mm accuracy. Volume is to be calculated either with a cut cone or a cylinder formula. For SET the cut-cone formula is used. Generally it is not determined by the law, how the log should be measured, but the measurement result accuracy is controlled. The measured log volume should obtain max. 4% deviation compared to manual control measurement.

Bark

All SET mills in Finland, except Kitee measure the mill measurement volume on bark. For the these mills like Kitee certain bark coefficients are used in different parts of the country to obtain volume with bark. The area bark coefficients used in the Kitee mill are presented in the following table 4. Kitee mill is located in southern Finland east part. (MMM 4.9.2001)

Table 4. Bark correction coefficients for spruce in Finland. (MMM 4.9.2001)

Spruce	*Southern Finland*		*Northern Finland*	
Debarked top volume class, cm	Westpart	Eastpart	Southpart	Northpart
	Volume addition; % to debarked volume			
13	12,7	11,3	14,5	17,9
15	12,5	11,2	14,3	17,4
17	12,2	11	14,1	17
19	12	10,8	13,9	16,6
21	11,7	10,7	13,7	16,1
23	11,5	10,5	13,5	15,7
25	11,2	10,4	13,3	15,3
27	11	10,2	13,1	14,9
29	10,7	10,1	12,9	14,4
31	10,5	9,9	12,7	14
33	10,2	9,8	12,5	13,6
35	10	9,6	12,3	13,1
37	9,7	9,4	12,1	12,7
39	9,5	9,3	11,9	12,3
41	9,2	9,1	11,7	11,8
43	8,9	9	11,5	11,4
45	8,7	8,8	11,3	11

Control

Basic internal controlling of the measurement equipment is done daily with the tube test. Results of the tube tests must be documented. The tube test result deviation can not exceed 2 mm in diameter and 2 cm in length from the determined tube size. The measurement equipment must also have an alarm system to prevent potential malfunctions.

The measurement results are officially controlled by measuring random sample logs. Usually one log out of thousand is randomly selected as a sample log. The amount of sample logs is pre-determined so, that the size of the statistical volume error between the manually measured volume and the measured scanner volume is not larger than 1% with 95 % confidence interval. The control measurement is done with manual cross-cut measurement with max. 1 m sections. The diameter is measured with 1 mm accuracy and the length with 1 cm accuracy.

The difference between the control measurement and the optic electronic measurement results can not exceed 4%. If this happens, the mill is responsible to re-calibrate the measurement equipment and cover the economical losses to timber sellers affected by the incorrect results during the time between noticing and repairing the incorrect results. (MMM 21.5.2001)

Supervision

The mill measurement supervision is done in each mill randomly usually once a year. There are 3 official measurers, who all control one part of the country. The supervision measurement focuses on deviations in the mill measurement. Monitored things are e.g. equipment, control, calibration and accuracy, documentation, instructions and keeping log patches separate.

4.2 Sweden

In Sweden the log-measurement is controlled by an national independent Timber Measurement Council (Virkesmätningsrådet, VMR). The actual measurement is done by Timber Measurement Organisations (Virkesmätningsförening, VMF), which operate in 5 different areas in Sweden.

Length

The log length is measured with 1 cm accuracy and the length is rounded down to module class minimum for log purchase and company internal purposes. The module classes run from 340 to 580 in 30 cm modules.

Diameter and volume

The measured diameter is the top diameter. The diameter is measured at the distance of about 10 cm from the top end. In case of curved or unshaped logs the measurement can be done at the distance of 8-12 cm. For timber purchase and internal purposes the diameter is rounded to each cm class middle. The length and diameter class centers and cylinder formula are used to obtain the volume for single log (m3toub) with .000 accuracy and for .00 for larger amount of logs for purchase purposes. For internal use certain correction coefficients are used to obtain the volume (m3fub) "close to Archimedes principle". The correction factors are different in the different parts of Sweden, but during autumn 2001, same coefficients will be used in the whole country. These coefficients for pine are presented in table 5 and for spruce in table 6.

Table 5. Swedish volume correction coefficients for pine. (Johansson 6.8.2001)

Pine										
Diam (cm) \ L (dm)	**28**	**31**	**34**	**37**	**40**	**43**	**46**	**49**	**52**	**55-**
11	1,29	1,3	1,31	1,32	1,33	1,34	1,35	1,36	1,37	1,38
12	1,26	1,27	1,28	1,29	1,3	1,31	1,32	1,33	1,34	1,35
13	1,23	1,24	1,25	1,26	1,27	1,28	1,29	1,3	1,31	1,32
14	1,21	1,22	1,23	1,24	1,24	1,25	1,26	1,27	1,28	1,29
15	1,2	1,2	1,21	1,22	1,23	1,24	1,24	1,25	1,26	1,27
16-17	1,18	1,19	1,2	1,2	1,21	1,22	1,22	1,23	1,24	1,24
18-19	1,17	1,17	1,18	1,19	1,19	1,2	1,21	1,21	1,22	1,22
20-23	1,16	1,17	1,17	1,18	1,18	1,19	1,19	1,2	1,2	1,21
24-27	1,15	1,15	1,16	1,16	1,17	1,17	1,18	1,18	1,19	1,19
28-31	1,13	1,14	1,14	1,15	1,16	1,16	1,16	1,17	1,17	1,18
32-35	1,12	1,13	1,13	1,14	1,15	1,15	1,16	1,16	1,17	1,17
36-	1,11	1,12	1,13	1,13	1,14	1,14	1,15	1,15	1,16	1,16

Table 6. Swedish volume correction coefficients for spruce. (Johansson 6.8.2001)

Spruce										
Diam (cm) \ L (dm)	**28**	**31**	**34**	**37**	**40**	**43**	**46**	**49**	**52**	**55-**
11	1,33	1,35	1,36	1,38	1,4	1,41	1,43	1,44	1,46	1,47
12	1,29	1,3	1,32	1,34	1,35	1,37	1,38	1,4	1,41	1,43
13	1,25	1,26	1,28	1,29	1,31	1,32	1,34	1,35	1,37	1,38
14	1,22	1,23	1,25	1,26	1,27	1,29	1,3	1,31	1,33	1,34
15	1,2	1,22	1,23	1,24	1,25	1,26	1,27	1,28	1,3	1,31
16-17	1,19	1,2	1,21	1,22	1,23	1,24	1,25	1,26	1,27	1,28
18-19	1,18	1,19	1,2	1,21	1,21	1,22	1,23	1,24	1,25	1,26
20-23	1,16	1,17	1,18	1,18	1,19	1,2	1,21	1,22	1,23	1,23
24-27	1,14	1,15	1,16	1,16	1,17	1,18	1,19	1,2	1,21	1,21
28-31	1,12	1,13	1,14	1,15	1,16	1,17	1,17	1,18	1,19	1,2
32-35	1,11	1,12	1,13	1,14	1,15	1,15	1,16	1,17	1,18	1,19
36-	1,1	1,11	1,12	1,12	1,13	1,14	1,15	1,16	1,17	1,18

In the case of unshaped logs (usually sweep) either the log length or the diameter can be reduced. In this case and also in the case of the coefficient corrected volume, both the measured and the corrected value must be expressed. In the invoicing the net-volume is always used.

Bark

All volumes are expressed without bark. The possible bark, ice and snow corrections by the operator are done according to first 10 cm at the log top. A specific formula and coefficients also exist for obtaining the debarked volume calculated according to top-diameter. The "debarked" volume formula is:

$$\text{Top-volume under bark (mm)} = d - (a + b \times d) \qquad (1)$$

Where,

d = measured top-diameter (mm)

a = coefficient a (mm)

b = coefficient b (mm)

The required coefficients are presented in the table 7 below.

Table 7. Bark correction coefficients in Sweden (Johansson 6.8.2001)

Wood species	**Pine**				**Spruce**			
Coefficient	***a***		***b***		***a***		***b***	
Part of Sweden	*west*	*east*	*west*	*east*	*west*	*east*	*west*	*east*
No bark	0	0	0	0	0	0	0	0
Thin bark	3,33	2,23	0,015	0,016	2,04	2,04	0,036	0,036
Medium bark	3,83	4,39	0,024	0,017	3,06	3,28	0,036	0,037
Thick bark	2,4	3,12	0,049	0,039	4,08	4,08	0,036	0,036

Example: Pine log with top diameter = 200 mm

Located in west Sweden

Operator judgement: medium bark

Top-diameter under bark = 200mm - (3,83 + 0,024 * 200mm) = 190 mm

Control

The control is done daily by the VMF with different kinds of tubes, boards and other measurement equipment. Test tubes can be either short (20 cm) or long (150 cm). The sawn timber boards are mainly used at all measurement stations to control the length measurement. Also a stick with metal plates is used to control the measurement equipment by attaching it to the measurement frame.

Controlling is also done with control logs. The sample logs are measured manually and the result is compared with scanner results. Deviation can not be more than 1%. During the control of the sample logs also the quality sorting accuracy of each operator is controlled.

Supervision

The supervising is done by VMF annually. (Johansson 6.8.2001)

4.3 Central Europe

The mill measurement at SET mills in the Central-Europe is based on several Austrian laws and Regulations.

- The ÖHHU - Österreichische Holzhandelsusancen – which includes common rules for logsorting and -grading and which also includes rules for e.g. contracts and claims.

- The measured volume at the mill measurement is determined by the Österreichisches Eichgesetz.

- In the spring 2001 was also introduced a ÖNORM L 1021 (Vermessung von Rundholz) with new rules of measurement e.g. for 3D measurement. At the moment the norm is optional, but SET will fulfil the requirements of these rules in 2002.

All the logs in SET CE mills are paid according to the mill measurement result.

Length

Normally used log lengths are 3, 4 and 5 m. Generally SET mills require 5 cm overlength. If this overlength is not delivered the length is rounded down to the next length class. In this case however the mid-diameter is measured at the middle of the module shortened log. The required overlength is not taken into account in the volume calculation.

The log length measurement should have the accuracy of 1 cm. Maximum allowed tolerances are:

- ± 1% (min 5 cm) for single measurement of one log length
- ± 0.4 % for the arithmetic mean of 10-20 length measurements from different logs.

Diameter and volume

The diameter is measured as mid-diameter from two directions in 20 cm section at the middle of the log. From 20 rounded measurement results the smallest rounded down value couple mean is used and rounded down to full 1 cm diameter class. Volume is calculated according to mid-diameter and cylinder formula. Maximum errors in measuring the diameter are:

- ±10 mm for single measurement.
- ±2.5 mm for the arithmetic mean of 10-20 diameter measurements measured along the length of one log.
- ±1 mm for arithmetic mean of 3-5 diameter measurements from different logs. (Kogler 30.7.2001)

Bark

In SET mills bark thickness is determined from the diameter measurement. For the log diameters up to 29 cm a 1 cm bark reduction is applied and for the larger logs a reduction of 2 cm. All the mills except Bad st. Leonhard and Plana mill do the mill measurement on bark. (Kogler 30.7.2001)

Control & supervision

During the autumn 2001 all Central European mills will have a common system for control of measurement equipment. The controlling is required in the laws to be done only on a yearly basis or when the measurement system is calibrated, but in practice the controlling in the mills is done daily. Both the controlling institute and the mills control the diameter with short tubes with different diameter. Also control logs are used. In this case totally 10 logs in 3 different lengths are measured manually and with the equipment once a week and test logs changed after about 3 weeks. Every 2 years or if the measurement systems is changed the Österreichisches Eichamt is testing all the measurement equipment at the mill according to the rule Österreichisches Eichgesetz. (Kogler 30.7.2001)

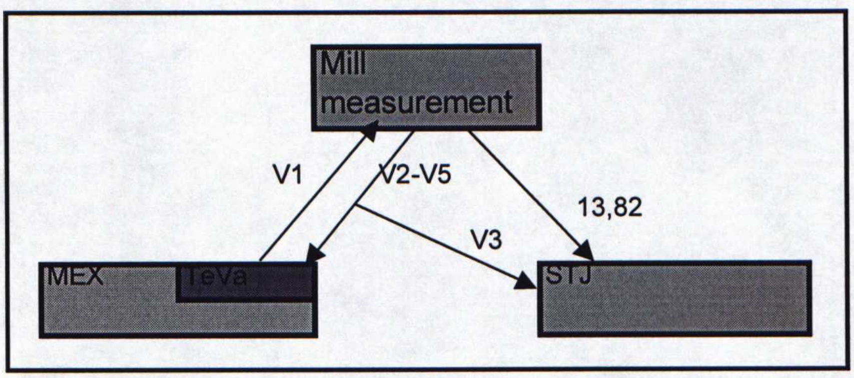
5 The use of timber measurement results

The use of measured log data is different in all operating countries. The measurement results are used for several purposes. The following functions in the different operating countries was examined.

- Timber purchase
- Sawmill internal reporting
- Company internal reporting (Flash-reporting)
- Sorting of sawlogs
- Raw-material department

5.1 Finland

The Finnish Log IT-system are based on two basic databases. The system named MEX is a broader SE forest system, which TeVa system (Mill log reception system) is one part of. STJ is the sawmills information system. The systems are presented in the picture 4 below.



Picture 4. Timber IT-systems in Finland

The measurement box in the picture 4 above presents the log-measuring unit and some assisting PC system. At every mill the same system combined to the log scanner is used for both MEX and STJ purposes, but in the Varkaus mill there are two scanners, which communicate with different systems. The mill measurement in Varkaus is done with Mikropuu 2D scanner, but for STJ and sawmill purposes the Rema 2D scanner results after the debarking are used.

The information flows presented in the picture 4 are following:

- Message V1 is the log reception patch data number, which contains e.g. transport number, contractor ID-number, truck data, and stand owner data.
- Message V2 is also log patch data, however this data is past log measurement data. This data consists of data lines, which each equal logs for one particular quality.
- Message V3 is a log by log data. This data is also stored to STJ as compressed files and used only case by case basically by the SE forest. The storage time depends on the mill, but generally it is about 5 years.
- MessageV4 is the control log data
- Message V5 is the test tube test data.
- Message 13 is sorted log data, which depends on the sawmill qualities e.g. length class, minimum diameter, quality and special sorting. This data is not a log by log data, but the logs are expressed by summarised groups and amounts. One file of message 13 contains the information for one working shift.
- Message 82 contains the running and stop-time information. There also exists one file for each shift of this data.

The operating principles of logscanners together with IT-systems depend on the manufacturer and model. Mikropuu 2D frames and Rema have to fetch themselves the necessary information from TeVa system while Mikropuu 3D system communicates with TeVa system so that TeVa system controls the flow of information. This problem with Mikropuu 2D scanners will be corrected before 3/2002.

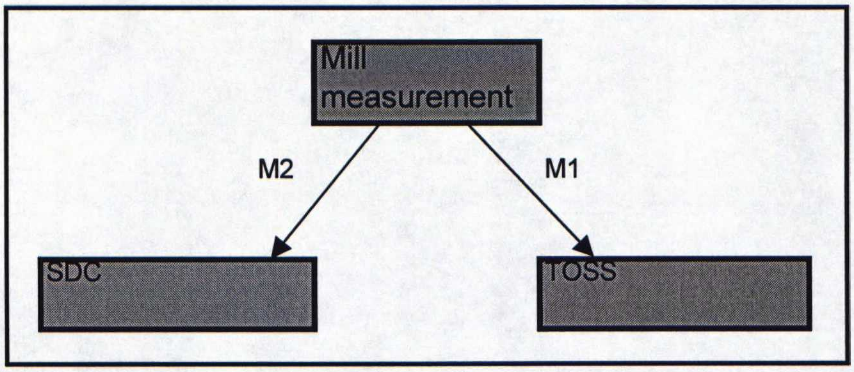
The daily functions connected to the change of log storage are depending on the mill. The number of the stored logs are only reduced according to sawn log data and the volume is then calculated from STJ steering data. In some mills this is done manually and in others automatically.

The reasons and practices for log sorting are relatively mysterious in Finland. Basically the sorting classes are based on previous experience. This means that the production planner empirically knows what on bark class equals a certain under bark class. Yet some tools exist for analysing and simulating already sorted logs.

For reporting purposes the information is obtained from several different locations. Basically the log consumption figures are gathered from TeVa system. In the mill the change in the log storage is the searched from STJ files. By combining these two data the total log consumption is obtained. This reporting procedure is yet very complicated. First of all the monthly invoiced log data from TeVa system is delivered by SET and then fetched again for log consumption figures. (Rautapää 4.10.2001)

5.2 Sweden

The Swedish IT systems, concerning logs, are also based on two paraller systems. The system named as SDC (Skogens Data Central) is a national system located in Sundsvall. TOSS is the sawmills own log information system, which stores the log data on a local server at each sawmill. This system is also used by SE forest department to check log deliveries. The Finnish system STJ mentioned above in the chapter 5.1 discussing log IT-systems in Finland is also in use in the Ala mill. The future target is to use either STJ or a similar system at all the Swedish SET mills. The current system is presented in the picture below.



Picture 5. Log-IT systems in Sweden.

The measurement box in the picture 5 above presents the log-measuring unit and some assisting PC system. In every mill the same system combined to the log scanner is used for both SDC and TOSS purposes.

The information flows presented in the picture 5 are following:

- M1 is message, which includes log by log data for the TOSS -system.
- M2 is also a log by log data. This message is sent to the SDC- system after each sift.

The operating principles of logscanners together with IT-systems depend on the manufacturer and model. Mikropuu 3D frame (Ala) and Rema 3D (Gruvön and Kopparfors) communicate with IT-system so, that the necessary information is sent automatically. With Rema 2D (Linghed) system the necessary information must be fetched. (Skansen 4.10.2001)

5.3 Central-Europe

Basically the Log IT systems in the SET Central-European mills is based on the system called EVK. Every log delivery for the mills is first registered in the EVK invoicing system. Then the delivery goes to the system called GEC-Measurement system, which is one part of the actual log measurement system. Detailed log information is then transferred directly to EVK-Database where the information is then fixed to corresponding delivery. The invoicing notes for log suppliers and forwarders are fetched from this system. (Zeilinger 27.11.2001)

6 Timber measurement equipment

6.1 Log-scanners at SET mills

Basically SET uses only three log measurement equipment manufacturers. This equipment includes both 2D and 3D scanners from every manufacturer. Present (8/2001) and estimated future timber measurement equipment at the mills is presented in table 8. The scanner models used by SET are presented in the following chapters.

Table 8. SET current and estimated log-scanners.

Sawmill	Current measurement equiment	Equipment 1/2002
Ala	Mikropuu 3D	
Gruvön	Rema 3D	
Honkalahti	Mikropuu 2D	
Kitee	Mikropuu 3D	
Kopparfors	Rema 2D	Rema 3D
Kotka	Mikropuu 2D	
Linghed	Rema 2D	
Tolkkinen	Rema 2D	Mikropuu 3D
Uimaharju	Mikropuu 3D	
Varkaus	Mikropuu 2D	
Veitsiluoto	Mikropuu 3D	
Bad St. Leonhard	Alstom 2D	Alstom 3D
Brand new line	Alstom 3D	
Brand old line	Alstom 2D	
Sollenau	Alstom 3D	
Ybbs	Alstom 3D	
Plana	Alstom 3D	
Zdirec	Alstom 2D	Alstom 3D

As table 8 shows on 8/2001 SET still has 9 2D scanners, but the investments done during the end of the year will improve the situation with 4 scanners, so that at the beginning of year 2002 only 5 mills would be using 2D scanners

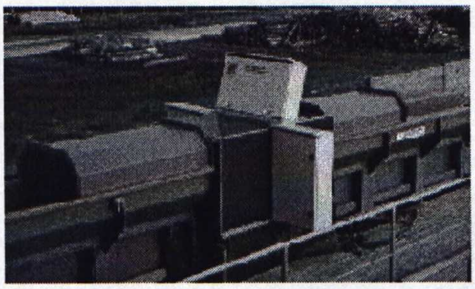
6.2 Manufacturers and models used by SET

6.2.1 Mikropuu

6.2.1.1 Opmes 202

Opmes 202 two direction scanner is an older version of the optical scanner 212 which measures the log horizontally and vertically. This scanner consists of photo transistor ramp and light unit with a parabolic mirror and halogen light. The length of the log is measured with photocells and encoder. The OPMES 212 scanner can measure the log sweeps with a continuous conveyor with low flights. Some technical data is presented below:

- 1500 measurements/second/direction out of which 150 measurements/second/direction are further processed
- Measuring range 640 or 768 mm
- Measuring accuracy of diameter - 1 mm
- Measuring accuracy of length - 1 cm
- Each direction has a processor of its own. (Mikropuu 13.11.2001)



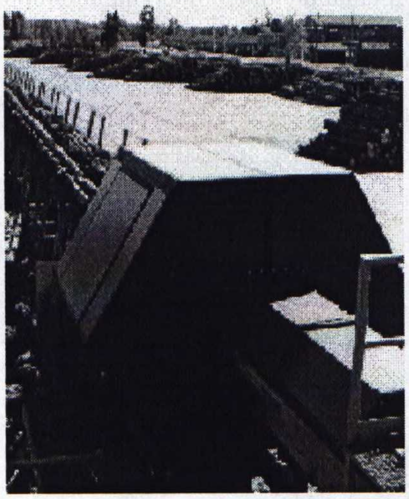
Picture 5. Opmes 212 scanner (Mikropuu 13.11.2001)

6.2.1.2 Opmes 604

This measuring system utilises matrix cameras and laser beams. The system produces a complete three-dimensional image of the log, which makes the diameter calculating throughout its length possible. (Mikropuu 13.11.2001)

To calculate volume, taper, sweep, oviform and other features of the log, the Opmes 604 scanner records the measures from the each used measuring direction with 25 mm intervals. Other technical data is presented below:

- 100 profiles of the log surface is obtained.
- Measuring range - 8 m
- Accuracy of diameter measurements - 1 mm
- length accuracy - 1 cm
- 50 measurements/second/direction
- Data handling with signal processors



Picture 6. Opmes 604 scanner (Mikropuu 13.11.2001)

For this scanner Mikropuu promises good possibilities for automatic quality sorting and sweep and taper detection, still it seems that many mills using this type of scanner still have problems to take these properties in use. However, Mikropuu has already tested a software update program, which would, according to Mikropuu, solve most of the problems mentioned above. This system should be assembled during the beginning of the year 2002 for all SET mills using this type of scanner.

6.2.2 Rema

6.2.2.1 Remalog 9000 series 2D

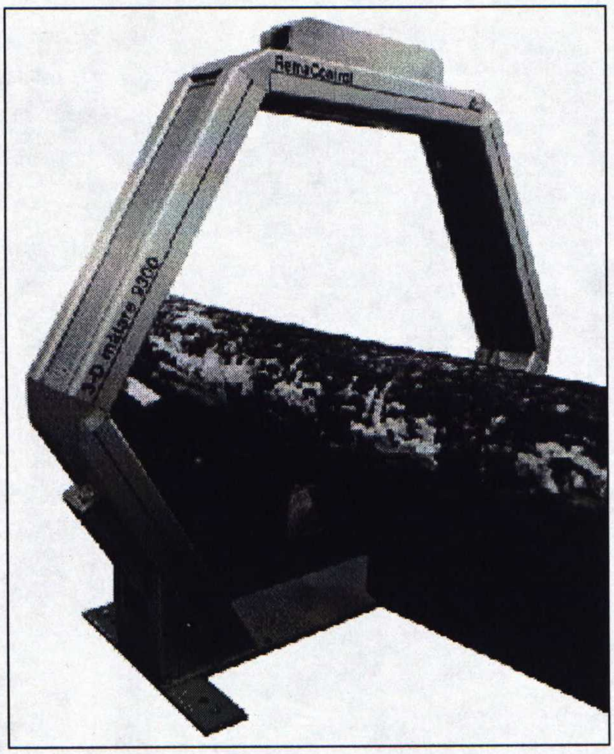
The measurement of this 2 direction shadow scanner type is based on diodes and LEDs. The number of receiving photodiodes is double compared to number of LEDs. Two closely spaced receiving photodiodes register the light from one LED. The diameter measures are determined according to the beams that reach the receiving photodiodes.

The calculation of the sectional volume in the shadow scanner 9001/9004 is based on the section area and the section length, with the first and last part of the log (normally 1dm) extrapolated. The section length can be either 1dm sections or about 1,5cm sections. For 1dm sections the area is based on filtering so, that the diameters are not allowed to increase from butt to top. The measuring itself runs from butt to top. For 1,5cm sections the smallest diameter for the last three sections is used. For two-directional scanners (9004) the mean diameter for the two directions is used and the measurement speed is 150 measurements per second. A correction value (like 0.99 or 1.01) could be used to calibrate the volume value. In the repetition tests max. 3% deviation in the log volume is obtained with debarked logs the accuracy values are 0,6 mm for diameter and 1 cm for length. (Larsson 7.8.2001)

6.2.2.2 RemaLog 3D

Rema 3D scanner is a 3 direction scanner based on laser point triangulation technique in which three measurement heads are placed with 120 degrees intervals. Each measurement head contains 16 measurement units. So the equipment provides a total of 48 measurement points around each log. The measurement speed is 250 measurements per second.

The Rema 3D scanner first filters all measured values and makes a standardised model of the log, based on 36 radius along the log. The calculation of the sectional volume uses these filtered data and some system parameters. For a typical installation (with typical parameters) the length of the sections will be around 20mm, the area for each section is based on 18 diameters (min. area for the section). For the first and last abt. 10cm of the log extrapolated area values are used. Repeatability tests have shown volume standard deviation values of less than 1% for logs around 200mm diameter. The Rema 3D scanners have according to Rema a quality sorting capability with 70 % accuracy. The accuracy of diameter measurement is 1 mm and 1 cm for length measurement. (Larsson 7.8.2001) (Chiorescu 2000)



Picture 7. RemaLog 3D scanner (Rema Control 13.11.2001)

6.2.3 Alstom

6.2.3.1 Selscan 3D

The log measuring system Selscan 3D utilises the sheet-of-light measuring principle. With the help of laser light and special high speed cameras the full log surface is scanned. Currently there are about 30 of these systems installed in sawmills mostly in Austria with operating speed from 80 m/min to 240 m/min. Some technical data follows:

- Resolution <2mm
- Measuring rate 400 contours/second
- Length measured with a pulse detector.

Picture 8. Alstom Selscan 3D scanner. (Alstom 2001)

6.3 Future trends of log measurement equipment

Basically the first SET future goals concerning log measurement in the short run are to detect the bark more accurately and succeeding better in the log quality sorting process, as it is now. This means, that the sorting result of the operator/ scanner should be closer to the sorting result obtained in the control measurement of the sample logs. In the long run SET goals concerning log measurement must be on the broader utilisation of x-ray technology. However, this goal requires that information obtained from the log interior should be utilised more efficiently by combining it with some production planning optimisation system.

The bark thickness and loose bark

There are two main concerns concerning the bark. Usually the bark thickness is uneven in different parts of a log and also usually some bark is missing. The missing bark creates recognisable problems with the diameter measurement. 10 % of the missing bark may in some cases cause an error of about 1 mm in the diameter measurement. Generally the relationship between missing bark and diameter error is linear and growing as the log size gets bigger. (Chiorescu 2000) Of course the unknown uneven thickness of the bark concerns serious problems in choosing the right debarked log class for an undebarked log. Also in this case the errors in the estimated diameter can be even bigger than the errors caused by the missing bark. Some research show that again even a 1 mm error in the diameter measurement may cause 5 % drop in the yield. (Usenius 26.10.2001)

There are several ways to solve these bark problems. One possibility is a system based on dielectric-constant or infra red light, but these systems only would determine the lack of bark, not its thickness. (Jäppinen 2000) To be able also to determine the thickness of the bark SET is mainly interested in 1-way x-ray solutions, which would be combined to existing 3D frames. This solution would be also most suitable as an investment. Rather high prices make 2- or more way x-ray systems irrelevant for these purposes.

Automatical log quality sorting

To sort the logs automatically and accurately to the right log classes according to their exterior is a feature that most of the scanner manufacturers advertise. Though, now all the scanner types used by SET are not able to achieve this goal. But in the near future with some development work it might be possible to improve the accuracy of the automatic grading compared to sample log grading. Researches have shown that 3D scanners can already give 5-10 % better results compared to conventional 2D scanners. Nowadays the manual grading accuracy can be already about 80%, but close to 100 % automatic accuracy would make it easier to determine the right log classes. However, in the future the sorting accuracy should be compared to finished products instead of the control logs. (Usenius 26.10.2001) (Jäppinen 2000).

Also knowing the external log quality is not enough in the future. There are many different kinds of x-ray scanner solutions available in the market. 2-way x-ray scanners roughly determine the location of knots, while 3-way system makes the picture a little clearer. SET and VTT (The Technical Research Centre of Finland) research has shown that with 4-way x-ray scanner the amount of information obtained from the log could be up to 15 % more than with a 3-way x-ray scanner. This information combined to the fact that one more x-ray measurement dimension costs around 0.2 –0.3 M EUR has convinced SET that 4-way solution would be the most suitable to be further developed. However, researchers view is that perhaps 5-6 x-ray directions might be needed in the future to determine the interior of the log accurately enough. (Vainio 20.9.2001)

The end of the chapter focuses on the future trends of log-measurement equipment. The manufacturers reviewed are the current scanner manufacturers used by SET and few others considered to be potential future deliverers.

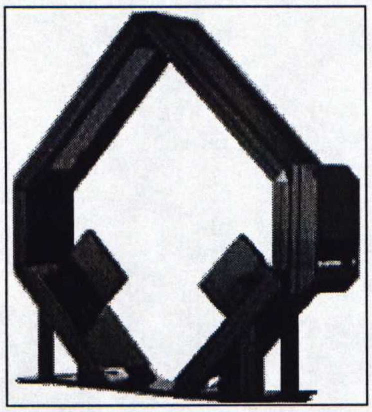
6.3.1 Mikropuu

Future trends of Mikropuu scanners are based on x-ray technology. In the future Mikropuu 3D scanner would be equipped with a separate one way x-ray scanner, which would focus on determining the bark. The estimated price for this equipment is about EUR 50.000-66 000. (Kuvaja 17.8.2001) SET has already done some pre-planning of the installation of this system to some Nordic redwood mill. Most likely the mill would be Uimaharju or Veitsiluoto. According to Mikropuu the first version of this system should be ready at the end of year 2001. In the future Mikropuu plans to update this x-ray system to also give a one way picture of the log interior.

6.3.2 Rema

Rema`s future trend is RemaLog Tina x-ray scanner, which has had older versions available in the market for a long time. The measuring system consists of measurement frame with two measurement housings with industrial x-ray tubes. Two detectors register the intensity of radiation from each housing. According to

Rema two directions are necessary to determine the curve of the log. In the convential log quality-sorting Tina provides the accuracy of 95-96%. Remas test runs also show that RemaLog Tina reduces the use of raw material by 2%. The investment costs for this x-ray scanner are 3,5-4 MSEK. (Rema Control 1997)



Picture 9. Rema Tina-scanner (RemaControl 13.11.2001)

Though Rema claims, that this x-ray scanner is able to determine the thickness of bark and reveal the inside of the log, Tina scanner can be considered relatively not up to date. Two x-ray measuring directions is not enough to determine the total interior of the log. With two direction the position of the knots can be determined, but the size and direction are impossible to estimate. Just to determine the bark the Tina scanner is highly expensive. In addition to that one application in Sweden at Finnforest Valås sawmill requires two more optical measuring frames to measure accurately.

Apart from Tina scanner Rema is currently developing a system for "conventional" scanners to determine the lack of bark. This system is based on UV-light and it is only able to determine whether bark exists or not, but not the thickness of it. (Larsson 7.8.2001)

6.3.3 Alstom

Alstom is planning a x-ray solution for logsorting. However, plans are still relatively open and the development work will take several years. (Kogler 30.7.2001)

6.3.4 Other manufacturers of log scanners

6.3.4.1 Pronyx

Pronyx is a Swedish manufacturer of log scanners. The first installation of their 3D scanner took place during the summer 2001. The 3D measuring frame, which is also installed in front of the sawline at SET Kopparfors mill, utilises camera technology, which have integrated pixel sensor, A/D converters, and image processor, all on the same chip. The technique gives good resolution with measuring frequency (up to 1000 profiles each second). The camera is also built with CMOS technique, which prevents problems with dark and wet bark and light wood.

During last year VMR (the Swedish timber measurement council) in co-operation with Trätek (Swedish Institute for Wood Technology Research) has started a project that should improve the measuring of undebarked logs. The system uses a technique that measures the light diffusion in the surface of different materials.

Pronyx has also started a further co-operation with VMR and Trätek that should result in a bark detection directly at the 3D-measurement frame. This is going to be developed during the autumn 2001 and it is planned to be installed in a test plant under March 2002.

SLU (Swedish University of Agricultural Sciences) has developed a method also to estimate the quality of logs according to their geometrical shape and a statistic database. For the top, middle and root logs it has been estimated that an accuracy of 80-95% could be obtained in the quality-sorting process. The studies continue with test-sawings to connect the measuring result with the ordinary sorting of logs. The first installation with quality estimation will be installed on an existing log feed in system with 3D frame in the end of year 2001. (Pronyx 2001)

SET has no experience of the Pronyx system in the log sorting purposes. However Pronyx scanner could be considered rather potential invest if all the planned future properties would be available in one measurement frame.

6.3.4.2 Microtec

Austrian company Microtec has developed an x-ray measuring equipment called Tomo Log. This system is available either with one or three 200 kV x-ray sources. The one source system is designed for log splinter detection, while the 3 source system is also able to measure the mean bark thickness, knot percentage or content and annual ring widths or distributions. (Microtec 2001)

The Microtec`s current x-ray system can not be considered very potential. Modern equipment with one x-ray source should be able to measure the thickness of the bark accurately. This Tomolog system is not able to determine the bark even with 3 x-ray sources. However it seems that Microtec system is able to handle the knot content of the log quite well. A potential future product might be a multi-camera 3D scanner of Microtec equipped with this Tomolog one source x-ray scanner. The purpose of the x-ray equipment should be in this case to determine the bark accurately.

6.3.4.3 Bintec

SET already has some experience of the Finnish Bintec x-ray scanners. At Koski Timber in Hämeenkoski, Finland a 3-way x-ray scanner has been installed for several years. However, this scanner has been mainly in test run use. The further installation for production use would have required new software. This fact together with an argument that an additional fourth x-ray source would provide significantly more information has convinced SET, that a new 4-way scanner will be installed in the Honkalahti mill. In the beginning this scanner will mainly operate in test run purposes, but the future utilisation will be in production. The test runs in form of repetition tests already at Koski Timber revealed that Bintec scanner gives very accurate measurement results, both on and under bark. The repetition tests also revealed concerning quality sorting that 84% of the logs judged to contain U/S- quality centerpieces, actually resulted in the U/S quality centerboards. In Honkalahti the new scanner will focus on finding out two different features of the logs; to determine the total knot mass of one particular log to be able to determine root logs more efficiently and to determine the distance between knots in case of middle logs. The knotless material would be utilised in the finger jointing. (Vainio 20.9.2001)

7 Measurement process factors

In this chapter the process factors, presented in the Timber Measurement Model are discussed as log sorting operator functions e.g. bark- and snow-correction. There are also many other process factors affecting to the timber measurement result. The other possible factors that might have been worth presenting here are the stability of the log during measurement and the light conditions of the measurement place. However, these factors are extremely difficult to be evaluated and presented. This is why they are omitted.

7.1 Operator functions

Here the studied factors are bark and snow/ice-correction done by the log sorting operator. This means that correction is done when some of the log bark is missing or when the log is covered with ice. The national corrections are presented at the table 9 below:

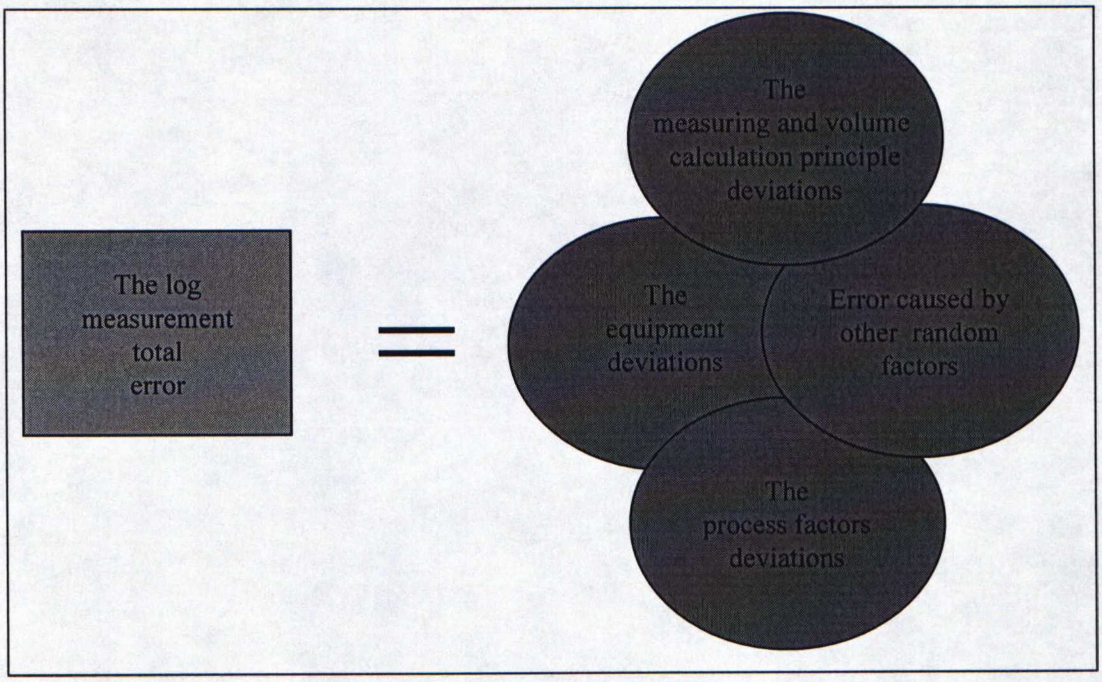
Table 9. Operator process factors.

	Bark correction	*Ice & snow correction*
Finland	Adjustable. Usually done with 20 %-scale.	Adjustable. cm or %- scale
Sweden	No, thin, medium or thick bark	cm -scale
Central-Europe	Bark or no bark.	cm -scale

Like table 9 shows the ice- and snow correction is relatively uniform in the different operating countries, but the bark correction is not. However, both the ice- and snow-correction and the bark correction practices can, in some cases, be very far from the suggested practices, mostly because of individual operator habits.

8 Timber measurement model accuracy and errors

To be able to estimate the errors or inaccuracies that exist in the log measurement process, we look back to the timber measurement model in the chapter 3. The reformed model, presented below, gives a picture of the different error factors.



Picture 10. The total error of log measurement result.

The different factors presented in the picture 10 error are discussed in the following chapters 8.1 -8.4.

8.1 Measurement and volume calculation principles error

Earlier attempts have been made to estimate the volume differences in different operating countries. Here is presented and discussed one earlier attempt called "Puumalainen study" to reveal the rough magnitude of the current accuracy of the national volumes. It is very difficult to estimate the total error caused by national measurement principles e.g. in the attempt presented in the following table some of these differences were not taken into consideration.

- The use of correction coefficients focuses only on the error created by the measuring and volume calculation principle error. The other inaccuracies presented at the total error picture 10, are not considered in case of the coefficients.

- National bark determination varies e.g. in Central-Europe the bark is either 1cm or 2cm thick.

- The amount of received overlength is impossible to estimate. Again e.g. in case of Central-Europe the optional 1m module reduction might create notable volume differences. In the "Puumalainen study" the average overlength was expected to be 5-10 cm for all the logs.

- Determining top diameter according to the mid diameter causes inevitable errors in case of Central-Europe.

- Generally by choosing the cylinder volume as internal volume the processed log volumes are all inaccurate.

Table 10. Conversion coefficients for national volumes to into a common standard (cylinder volume under bark) (Puumalainen 1999)

	Austria (Mid-diameter)	Finland, Pine (Top diameter)		Finland, Spruce (Top diameter)		Sweden (Top diameter)		
Average diameter on bark, cm		*South*	*North*	*South*	*North*	*Pine Top volume*	*Spruce Top volume*	*Total solid volume*
15	1,08	0,89	0,87	0,82	0,78	1,36	1,29	1,01
19	1,07	0,92	0,90	0,89	0,86	1,28	1,23	1,01
20-29.9	1,06	0,91	0,90	0,91	0,89	1,22	1,18	1,01
30-39.9	1,05	0,88	0,89	0,91	0,88	1,15	1,12	1,01
40-49.9	1,04	0,86	0,88	0,89	0,86	1,11	1,09	1,01

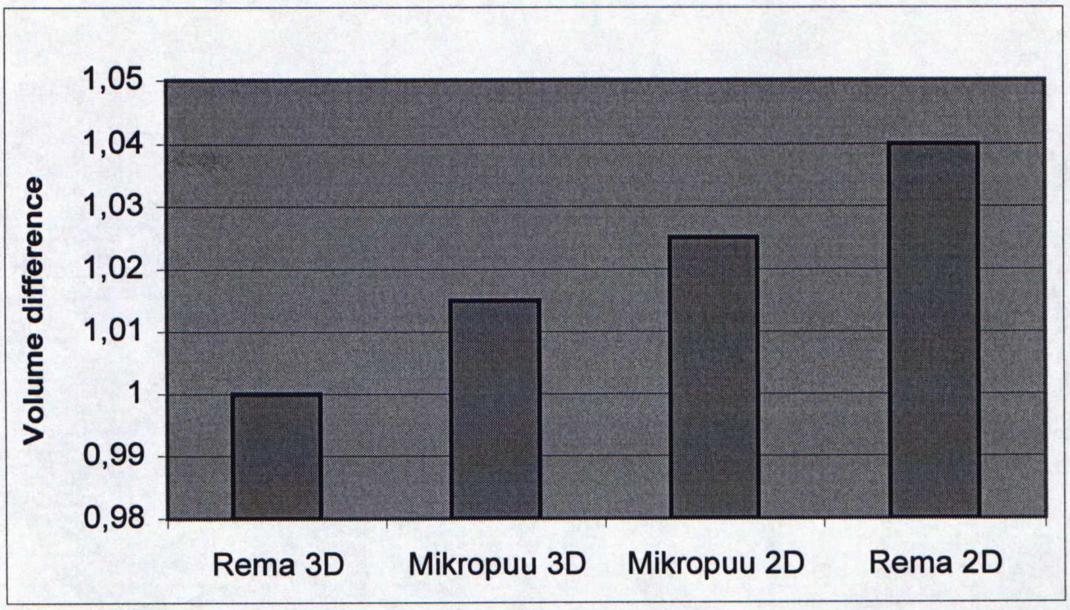
The standard volume was according to this study obtained from national reported volume by multiplying it with a respective coefficient from table 10. In case of Finland all mills except Veitsiluoto are located in southern Finland.

If we look at the table 10 in detail, we can note that the magnitude of the error caused by different measuring principles, in spite of the inaccuracies mentioned above. The difference in the national log volumes can, according to this study, be now up to 20 %.

8.2 The equipment error

The volume difference between different log scanner models and manufacturers is very hard to determine without proper test runs. However, some assumptions can be made from own tests done by the manufacturers. According to the scanner manufacturers used by SET the volume difference between 2D and 3D scanners is 1-4 %. According to Rema for their equipment the difference is about 4 % for Alstom about 2,5 % and for Mikropuu around 1%. In each case 2D scanner volume has bigger values. (Mittermueller 31.8.2001) (Larsson 7.8.2001) (Kuvaja 17.8.2001)

The difference between the Nordic manufacturers can be estimated according to the information that in SET Veitsiluoto both Mikropuu 3D and Rema 2D equipment were in use at the same time. The volume was then observed and calculated to be 2,5 % bigger with Rema 2D equipment. (Järveläinen 11.7.2001) This information here is combined to the volume assumptions done by manufacturers. The estimated volume differences between the Nordic scanner models are presented in picture 11.



Picture 11. Nordic scanners and volume differences

The volume differences concerning Alstom scanners compared to Nordic ones are impossible to estimate with current material. The future research done by The Technical Research Centre of Finland (VTT) can reveal more about the accuracy and volumes of Alstom equipment and confirm the numbers concerning the Nordic scanners presented above. These tests should be ready at 3/2002 and they focus on 3D scanners and more accurately in the following things:

- Handling the measurement data and the following determination of the right log class.
- The affect of number of measurements on the forecasting the measurement parameters.
- The ability to determine the log interior according to the external geometric.
- The measurement accuracy concerning taper, curve and sweep. (Usenius 26.10.2001)

8.3 The process factors error

The biggest national difference in the process factors are caused by the operator. The ice/snow- and the bark correction systems are not similar in all the operating countries. Especially the bark correction at the Central-European mills is very different from the Nordic ones. However, it must be said that despite of the similar instructions in the Nordic mills the actual practices concerning operator, bark correction can be very different. Also both ice/snow- and bark correction are done according to the first 10 cm at the log top, because this is the part of the log, in which the measurement is done. This fact may create a slight error, because usually the missing bark was located at the center of the log, in other words where the log has been processed during transportation. The rest of the process factors are somehow linked to the equipment error. The light conditions at the measurement place and the stability of the log during measurement could also be included in the equipment error.

Totally the process factor errors can not create bigger difference than ±2 % to the log volume. The biggest factor in this error is clearly the "missing bark judgement". It has different instructions in all the operating countries and in addition to that it is done more or less differently in each mill. However, there is a good possibility to correct this error in the future, if the missing or even the total bark of the log can be detected automatically.

8.4 Other random factors error

These unknown factors are always present when a measurement or test is done and accurate magnitude of these errors is impossible to estimate. To be able to build up a risk analysis model and to estimate the value of the total error of the log measurement, from this point in this study, the error caused by random factors is excluded. This is based on the fact that all the SET measurement equipment and practices are equipped with an automatic alarm system, which aborts the measurement process if an error is noticed.

9 The developed solution

Based on the things dealt in the previous chapters the following suggestion as SET internal volume was made:

9.1 The common "SET internal volume"

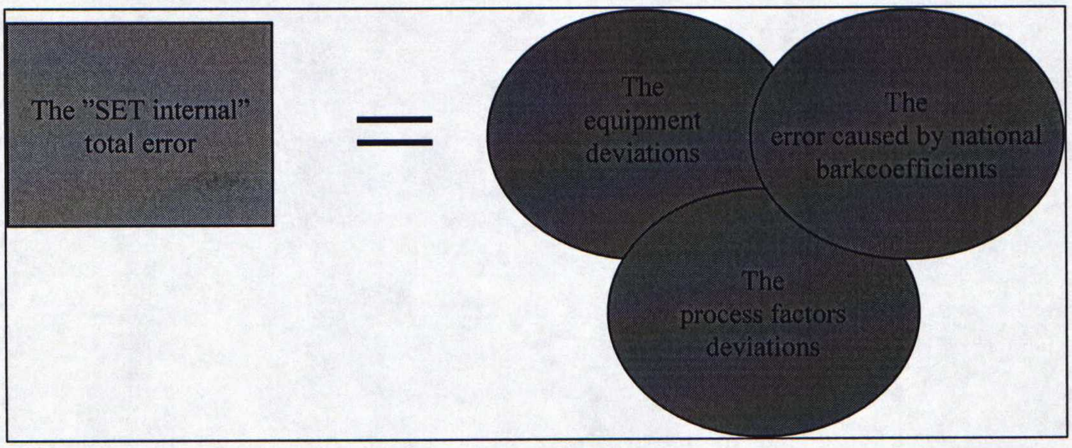
The common technical measurement would be the easiest way to carry out "the common SET volume ". The logs would be measured in the same way on bark in each country. National and area bark coefficients would be used to determine the volume under bark. The correction coefficients, considered to be another alternative, are impossible to calculate accurately and they must be updated. This was already mentioned and discussed in the chapter 8.1.1.

The advantages that the common technical measurement gives are multiple:

- The ”real” delivered volume would be measured in each country.

- Uniform and updated log stores. Especially Swedish mills have struggled with problems concerning inaccurate log storage. In some cases the errors at the inventory process, determining the size of the storage, can now be even 15 %. (Johansson 6.8.2001)

Basically if we look the technical measurement choice together with the error of the log measurement model presented in picture 10, we see that when an uniform measuring system could be created the "measurement and volume calculation" error could be almost totally excluded from the model. Only estimations concerning the making of the log "debarked" have to be made on a national level.



Picture 12. The effects of "SET internal" on the timber measurement model.

The accuracy of the model would get even better when process factors e.g. missing bark judgement in each mill could be made more uniform. However, this would cause difficulties in measuring the national volume used for log purchase purposes. The random factor are inaccuracies, which are impossible to control. The correction attempts of the equipment error, would lead to errors in the national measurement.

9.1.1 The risk analysis of the "SET internal volume"

Based on the discussion in chapter 8, it is assumed here that the following errors in the "SET internal" log measurement result is created by each factor. These relatively pessimistically estimated error factors are based on interviews with the log measurement equipment manufacturers and researchers.

- The equipment error ± 3 % error.
- The process factors ± 2 % error.
- National coefficients for "debarking" ± 2%

There are several methods to determine the total error of these factors. Two of them are discussed here; the "worst case analysis" and the statistical combination of the tolerances. (Karjalainen 1992)

9.1.1.1 The "worst case" analysis

In the worst case analysis the error factors are understood as sub-tolerances for the total error. This means that the total error is the sum of all the sub-errors. With the values presented in the previous chapter 9.1.1 the total error would be,

$$\begin{aligned}\text{Total error} &= \pm(\text{ equipment error + process factor error +"debarking error"}) \qquad (2)\\ &= \pm(3\% + 2\% + 2\%)\\ &= \pm 7\,\%.\end{aligned}$$

Here it can be seen, that the estimated error of the measurement would be around 7 %. So in the worst possible case the difference between two volumes can be as big as 14 %.

9.1.1.2 The statistical combination

In the statistical combination model the square of the total error is the sum of the squares of the sub-tolerances. In this case;

$$(\text{Total error})^2 = \pm[(\text{equipment error})^2 + (\text{process factor error})^2 + (\text{debarking error})^2] \qquad (3)$$

$$\text{Total error} = \pm 4{,}12\,\%$$

As it can be seen the calculated difference can be around 4 %, which implies that in the worst possible case the difference between two compared volumes can be even 8 %.

9.1.2 *Technical determination*

Basis of the SET internal volume must be a technical definition so, that the "worst" equipment in the company is able to measure it. The easiest solution for this is to use a volume based on the sectional (30 cm) volume (Mikropuu principle). This system gives certain benefits:

- The scanners in Finland need only a little programming and Rema scanners in Sweden only minor changes, while only Central-European Alstom equipment needs major changes.

- This sectional volume also give the most uniform results to Archimedes principle. This happens because the selected system is not so sensitive for filtering problems concerning knots, root enlargement and loose bark.

The technical determination of Mikropuu measuring principle is presented below:

The determination of the diameter used in the volume calculations depends on the scanner type. The minimum value obtained in different directions from the selected distance is calculated as a top-diameter. For 2D scanners the average of minimum values is used. For 3D scanners the top-diameter is calculated from the diameter representing the cross-section area.

The obtained measures (measuring filtering)and the log edges (edge filtering) are filtered so that totally wrong measures are replaced (linearised). The linearisation is done, by calculating the assumed correct measure, at each recording point in the error area. The correction is needed e.g. when a hanging bark causes an incorrect measure data.

The volume calculation includes the following steps:

1. The calculation is started from the root end. The starting distance from the root can be controlled. From the point selected a diameter used for the root diameter calculation is found by comparing it to the measures beside it. If the chosen value is close enough to measures close to it, is the chosen value, ***Dt*** is used. With this value the volume of a cylinder-piece, **Vtyvi** with a length of the root straightening distance is calculated. For StoraEnso mills the root straightening distance is 100 mm.

2. From this point on, towards the top of the log, the minimum diameter of the filtered values, is searched for the next volume piece. When the length of a volume-piece is obtained from the root straightening distance, the chosen minimum diameter is used as a first volume-piece minimum diameter ***Dmin***. As a ***Dmax*** value the minimum value of the previous volume-piece is used. In the first case it is the ***Dt*** value. The volume of the piece is calculated with a cut cone formula:

$$T\,pala1 = (Dmin^2 + Dmin * Dmax + Dmax^2) / 12 * Tppit \qquad (4)$$

Where,

Tppit =*The length of the volume piece (For StoraEnso mills 300 mm)*

T pala1 =*The volume of the volume piece calculated with a cut-cone formula.*

3. The calculation goes on with the next volume piece so that the used minimum diameter value, ***Dmin*** of the previous piece, is used as a maximum diameter ***Dmax*** for the next volume piece.

4. Again the minimum diameter out of the filtered values is searched. The obtained ***Dmin*** value is used again in the formula 1, when calculating the volume of the next piece.

5. The calculations with the following pieces go on as described in the points 3 and 4 until the sum of the volume-pieces length is longer than the log length reduced with the top straightening distance. The last interrupted piece, with a length shorter than the normal volume-pieces, is handled in the same way as the ones with normal length, except when the length of the interrupted piece is used as the **Tppit** -value. To this value is also added an error caused by the difference between the length-measurement accuracy (10mm) and the measures recording piece (25mm), if the length would be handled in units of the recording (volume) pieces. The found minimum diameter from the starting point towards the root of the log is used as a ***Dmin*** -value.

6. Finally the same ***Dmin*** value and the cylinder formula are used to calculate the volume for the top-piece of the log.

7. The final volume for the whole log is a sum of the calculated volume pieces:

$$\mathbf{V = Vtyvi + V1 + V2 + ...Vn + Vosa + Vlatva} \quad (5)$$

8. The volume of the log is expressed as a rounded liter value with 0.1 liter accuracy.

9.1.3 Bark reduction

As mentioned above the bark reduction or obtaining the volume under bark would be carried out with national bark coefficients. Here are presented the sources for these national coefficients. In some cases the coefficients are available on a table form, but the later utilisation will require their transformation in to an equation-form.

Finland

The Finnish coefficients are available at The Finnish Forest Research Institute (METLA). Several publications study this factor, but the coefficients or equations for this particular purpose are not calculated. The calculation process should be started from the similar coefficients that exist for Kitee mill for adding bark. The required METLA publications are:

- Veijo Heiskanen and Pentti Rikkonen. Bark amount in coniferous sawlogs and factors affecting it. Folia Forestalia 250. Metsäntutkimuslaitos. Institutum Forestale Fenniae. Helsinki 1976

- Pentti Rikkonen. Volume of coniferous sawlogs based on top diameter over bark. Folia Forestalia 684. Metsäntutkimuslaitos. Institutum Forestale Fenniae. Helsinki 1987.

Sweden

The bark reduction in the case of Sweden can be done with the same coefficients that are used already now. They are presented in the chapter 4.2.

Central-Europe

In the Central-European mills the bark reduction could be done with two different formulas. These formulas are called "Peintinger" or "Güde - Hudecek" and a table called "Schönbrunner Tabelle". The "Schönbrunner Tabelle" table was created by Forestry Research Office Baden-Württemberg, Germany. (Kogler 30.7.2001)

10 Conclusions

At the beginning of the thesis two alternative solutions, correction coefficients and technical solution were considered. The technical solution turned out to be the only possible right solution from the beginning because of two main reasons. First, the possible inaccuracies, that the technical solution might contain would be also included correction coefficients together with further errors. So, in other words the technical solution would create more uniform volumes. Secondly, The calculation process of the coefficients would require a lot of assumptions to be made in order to estimate the actual log volumes from the currently measured ones. This procedure should perhaps be also repeated annually. After these arguments it should be clear, that certain correction coefficients for national volume correction should not be considered.

The technical solution itself does not give an absolute correct solution to the problem. According to the "worst case" analysis which simulates the worst possible situation the inaccuracies remain at ± 7% level, if all the error factors at one particular mill add up. The most likely case is, that the inaccuracies remain at ± 4% very maximum level. The precise magnitude of the error is impossible to determine, mainly because of the process factor errors. But in the future by getting an accurate information both of the missing bark and the bark thickness the errors in the common measurement could be reduced to a max. ± 3% level, containing only the error caused by the different equipment. It must be stated here that the error levels calculated at the risk analysis contain lot of assumptions. However, if we look at the 10-20% errors that current national volumes have, according to the "Puumalainen study" presented in the chapter 8.1, we must notice that in the worst possible case the inaccuracies after the use of "SET internal" can still be from up to 14 %. This fact recommends that the implementation of "SET internal" should be carefully considered with a broader group in order to get an objective view of the project. The first task of the this team should be to evaluate, whether the whole "SET internal" project is worth implementing. The alternative solution could be, that the present yield figures in the monthly reporting could be represented with figure expressing the relation of the reported yield figure to some annual trend. Yield figures could be in this case compared nationally.

If "SET internal volume" is implemented all the company needs should be taken into consideration in the possible implementation process. All the necessary organisations should be represented in this process right from the start. These organisations include surely SET IT, production and finance teams. E.g. the possible implementation of "SET internal volume" would surely cause problems with the IT-systems. Current national volumes can not be omitted and must be measured also in the future. But for sawmills and company internal reporting the new volume could be a handy tool. However, national volumes must also be available for controlling the purchased and delivered volumes and also for comparing the yield trend for one particular sawmill.

All in all comparing yield figures on a monthly level can be questioned. There are several question marks also on the product side concerning e.g. finished and unfinished goods. The figures for reporting both for the raw-material and the products are, at least in the Nordic mills, delivered itself by the sawmill. This fact can in some cases jeopardise the objective figures for the reporting. However, comparing the yield figures of one particular mill in a longer period must be considered relatively reliable. However, one future project could also be to evaluate the reliability of sawn goods information used for yield calculation.

11 Suggestion as future actions

Here are gathered some recommended future actions.

- The possible implementation of the "SET internal volume" must be done in a deep co-operation with SET IT, finance and production teams. The first task of the project team should be to analyse the project objectively.

- The national bark reduction coefficients must be calculated and expressed in a equation form. The assistance of national institutes must be considered.

- A comparison between current national volumes and "SET internal" must be made. This data is already available from Ala and some SET Finnish mill after the national bark reduction functions are determined. In case of Sweden the result can be compared with the coefficient corrected volume that already now exists in Sweden. The same comparison must be done at some CE mill, after Alstom has processed the measuring principle.

- For several months the current yield figures must be presented besides the "SET internal volume" to be able to monitor the yield trends for the mills.

- In case the Mikropuu measuring principle is impossible for other scanner manufacturers to copy, then every manufacturer's most accurate measuring principle must be considered to be measured as "SET internal volume". However, in this case the accuracy of the obtained volumes can get significantly worse.

- In the equipment development SET should focus on the bark detection. By getting an accurate information both of the missing bark and the bark thickness the errors in the common measurement could be reduced to ± 3% level, containing only the error caused by the different equipment.

- The process factors, that the log sorting operator controls should be made more accurate like mentioned earlier, e.g. a 10 % error in the missing bark judgement may cause a 1mm error in the diameter measurement. This may seriously increase the log consumption.

- The 2D scanners in Finland should be calibrated to the most accurate value. Now, mostly because of the pressure from SE forest, some scanners are calibrated to measure larger volumes deliberately. This also causes huge raw-material costs annually.

- Serious discussions of the production planning procedure and determination of the log classes should be made at the Nordic mills. Now the debarked volume and log-class is often estimated without any tools by the production planner. Wrong log classes might again cost a fortune annually.

12 Summary

This aim of this Master Thesis was to find a solution to a problem concerning company internal reporting. The different national measuring principles for sawlogs in Central-Europe, Finland and Sweden have created problems in comparing log consumption and yield figures in the company internal reporting.

In the Thesis two alternative solutions were considered; To determine and calculate the volume correction coefficients for each operating country or to develop an uniform technical measurement system to measure common volume for the internal use in the each operating country besides the required national volume.

The research process was focused to determine national mill measurement practices for sawlogs including more thorough study on measurement equipment, national measuring and volume calculation principles, and other process factors related to the log mill measurement. The summary of these facts is presented as a table in the appendix 1. The reporting and IT-systems concerning log volumes were also studied for possible further implementation. As a thesis "by-product" can be considered the review on future outlooks of the potential logscanner manufacturers.

The clear result of the study was to carry out the volume harmonisation with a technical solution. All in all it would be a lasting solution in the future and also the accuracy factors favoured this solution. By determining the considered volume correction coefficients, only part of the total factors affecting the measurement result would be taken into consideration. The study recommends that the common internal volume would be based on the volume calculation used in the logscanners at the Finnish mills. This solution would require the minimum amount of programming because of its simplicity. This solution was also considered to be the fastest to implement. With this technical solution the differences between national volumes could be reduced to a very maximum ± 7 % level. Most likely the difference would be much smaller having a maximum magnitude of ± 4 %. At the moment the compared yield figures might have differences around 10-20%. The calculation of difference between national volumes at the risk analysis has, however, included a lot of assumptions. The accurate definition of the future error is impossible to determine mathematically, mostly because of the unobservable magnitude of the process factor errors, that occur during the log measurement. This makes almost every guess of the error magnitude equally good. However, in the future with by eliminating both the missing bark problem and the error caused by national bark coefficients the results of the common log measurement could be considered very accurate.

Though the thesis finds a solution for the existing problem, it still carefully questions the total project of volume harmonisation. Comparing inaccurate yield figures, built of information from various sources on a monthly level does not reveal accurately the operation of a one particular sawmill. However, it must be stated that the yield figure monitoring with annual trend is currently the best available tool for monitoring the raw-material use on a company level.

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Appendices

Appendix 1

	Central-Europe	Finland	Sweden
Measurement equipment	Generally Alstom Selscan 3D scanners, except Alstom 2D at Brand mill old line.	4 Mikropuu 3D scanners and 3 Mikropuu 2D scanners	1 Mikropuu 3D scanner, 2 Rema 3D scanners and 1 Rema 2D scanner.
Volume calculation	Cylinder formula	Done in maximum 30 cm pieces. Cut-cone formula.	Cylinder formula.
Diameter used in the volume calculation	Mid-diameter. From 20 rounded cross-measurements the smallest rounded down couple mean is used and rounded down to cm- class minimum.	Smallest and biggest values for one particular volume piece of a log.	Top-diameter (10 cm from the log top) rounded to cm- class center
Length used in the volume calculation	Delivered length with 1 meter accuarcy. If 5 cm overlength not delivered, one meter module shortened.	Delivered length with 1 cm accuracy.	30 cm length-class minimum.
Bark	Volumes expressed under bark. 1 cm bark for logs <29 cm mid-diameter and 2 cm for bigger logs.	Volumes are expressed with bark.	Volumes expressed under bark. National coefficents for bark reduction.
Operator bark correction	Yes or no bark.	Adjustable. Usually done with 20 %-scale	No, thin medium or thick bark.
Operator ice/snow correction	cm- scale	cm- or %-scale	cm- scale
Control	Tube test daily. Selected control logs.	Tube test daily. 0,1% sample logs.	Tube test daily. Random control logs.
Supervision	every 2 years or after calibration.	Annually	
Note!		The measurement principle is not determined in the law. Only the result is.	Both top-volume under bark and solid under bark volume are reported. Solid volume is obtained with national coefficients